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DIURNAL VARIATION OF SURFACE PRESSURE OVER THE NORTH ATLANTIC OCEAN

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ABSTRACT

Data from the Ocean Vessel Stations have been used to determine for each month (1) the daily variations of mean surface pressure, (2) the 3-hour mean-pressure tendencies, and (3) the phases and amplitudes of the first three harmonics of the daily variations. Some implications of the results are discussed briefly.

1. INTRODUCTION

With partial support from the U. S. Weather Bureau through a contract with its Office of Climatology, a study is being made of the utilization of ship observations in the specification of climatic conditions over the oceans. A phase of this study is concerned with diurnal variations of meteorological elements over the North Atlantic Ocean. This article is concerned with the diurnal variation of one of these elements, the surface (sea level) pressure, hereafter called simply "pressure."

The observations taken aboard the Ocean Vessel Stations (OVS) permit, for the first time, an analysis of diurnal variations over the ocean without the assumption that islands may be treated as representative of oceanic conditions. While the very presence of the ship may have some disturbing influence, any such effects should be considerably less significant than the presence of an island.

The OVS take surface observations at 3-hr. intervals. Thus, eight observations per day are available.

2. DATA

The OVS data were tabulated by the National Weather Records Center in the form of 3-hourly mean pressures for each individual month of the study period. The numbers of observations used in computing these means were also provided. To obtain a grand mean for a particular observation time and particular month, over the complete study period, each of the tabulated 3-hourly means, say the 0000 GMT means for December at station A, was multiplied by the number of observations used to construct it, and the results for all years of the study period were added together and divided by the total number of observations.

TABLE 1.—*Position of Ocean Vessel Station, portion of record utilized, and average number of observations employed in computing 3-hourly mean pressures*

Station	Latitude (° N.)	Longitude (°)	Portion of record utilized	Average number of observations per 3-hourly mean pressure
A	62.0	33.0 W	Jan. 1948–June 1954 [1]	155
B	56.5	51.0 W	July 1948–June 1955 [2]	184
C	52.8	35.5 W	Jan. 1947–May 1955 [3]	241
D	44.0	41.0 W	Sept. 1949–June 1955 [4]	164
E	35.0	48.0 W	Sept. 1949–May 1955	168
H	36.7	69.6 W	May 1949–June 1954	154
J	52.5	20.0 W	June 1950–Dec. 1954 [5]	96
K	45.0	16.0 W	July 1949–Dec. 1953 [6]	92
M	66.0	2.0 E	July 1948–Dec. 1953	166

[1] Less January and March 1954.
[2] Less August and October 1948, July and December 1953, January and December 1954, and April 1955.
[3] Less March 1949, and January and April 1955.
[4] Less December 1954, and April and May 1955.
[5] Less all of 1952.
[6] Less all of 1952, and May 1950.

TABLE 2.—*Mean monthly pressures (mb.) and mean departures from the mean monthly pressures. * denotes maxima of DVMP, ** denotes minima of DVMP. Time is in Local Standard (Zone) Time*

Time	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
STATION M												
00	−0.43**	+0.31*	+0.05*	−0.54**	+0.35*	+0.05	+0.20*	−0.04	+0.25	+0.00	+0.52*	−0.30
03	−.03	+.01	−.15	−.54**	−.25	−.25**	−.20	−.24	−.05	−.10	+.12	−.30
06	−.13	−.39**	−.25**	−.34	−.45**	−.25**	−.30**	−.34**	−.25**	−.20**	−.08**	−.40**
09	+.27*	−.29	−.05	+.06	−.15	−.05	−.20	−.04	+.05*	+.10*	+.22*	+.20*
12	+.27*	+.01	+.25*	+.26	+.05	+.05	+.10	+.06	−.05	+.10*	−.08	+.20*
15	+.07	+.01	+.25*	+.46*	+.15*	+.15*	+.20*	+.26*	−.15**	−.10**	−.28**	+.10**
18	−.03	+.11	−.05**	+.46*	+.05**	+.15*	+.10**	+.16	−.15**	+.10*	−.18*	+.20
21	−.03	+.21	−.05**	+.16	+.25	+.15*	+.10**	+.16	+.35*	+.10*	−.28**	+.30*
Mean monthly pressure	1000.73	1000 .79	1009.25	1003.04	1016.95	1012.65	1011.20	1008.74	1006.35	1006.40	1003.68	1000.00
STATION A												
01	−0.04	−0.33	−0.06	−0.26	−0.01	+0.07	−0.09	+0.31	+0.18	−0.07	+0.04	−0.82**
04	−.34**	−.71**	−.59**	−.66**	−.41**	−.33**	−.39**	−.39**	−.19**	−.30**	−.21**	−.51
07	−.24	−.57	−.52	−.26	−.11	−.23	−.19	−.29	−.02	−.14	+.18*	−.27
10	+.16	+.13	+.04	+.24	+.09*	+.07	+.21*	−.09	+.10*	+.11*	−.14	+.54*
13	+.26*	+.33	+.39*	+.44*	+.09*	+.17*	+.21*	+.11*	−.05	−.09	−.16	+.13**
16	−.24**	+.39	+.22**	+.14**	−.11**	−.13**	+.11	−.09**	−.27**	−.12**	−.26**	+.30
19	+.16	+.77*	+.42*	+.34*	+.09	−.13**	+.11	−.09**	−.16	+.22	+.05	+.36*
22	+.26*	−.05	+.07	+.04	+.12*	+.47*	+.01	+.51*	+.37*	+.35*	+.50*	+.28
Mean monthly pressure	992.34	995.63	1003.74	1008.76	1015.91	1010.13	1010.79	1008.99	1006.26	998.36	1000.59	993.68
STATION B												
00	+0.12	0.00	+0.03	+0.15	+0.04	+0.18	+0.24	+0.14	+0.01	+0.07	+0.02**	−0.21
03	−.28	−.50**	−.43**	−.25	−.26**	−.22**	−.16	−.26	−.29**	−.23**	+.02**	−.51**
06	−.38**	−.40	−.23	−.35**	−.16	−.12	−.26**	−.36**	−.19	−.13	+.02**	−.31
09	+.02*	+.30*	+.17*	−.05	+.14*	−.02*	−.06	−.06	+.11	+.17*	+.32*	−.01
12	+.02*	+.30*	+.17*	+.05*	+.14*	−.02*	−.06	+.04	+.21*	−.03	+.02	+.09*
15	−.18**	−.10**	−.13**	−.15**	−.06**	−.12**	−.06	+.04	−.09**	−.33**	−.28**	−.01**
18	+.22	+.20*	+.07	+.15	+.04	−.02	−.06	+.24*	+.01	−.03	+.02	+.59*
21	+.42*	+.20*	+.37*	+.45*	+.14*	+.38*	+.44*	+.24*	+.21*	+.47*	+.18*	+.39
Mean monthly pressure	1003.48	1006.40	1008.33	1011.75	1014.06	1010.62	1011.06	1009.16	1007.59	1005.13	1007.08	1004.71
STATION C												
01	+0.15	−0.21	+0.42*	−0.15	−0.24**	−0.21	+0.04	+0.14	−0.14	−0.30	−0.08	−0.26**
04	+.05	−.41**	−.28**	−.65**	−.24**	−.51**	−.36**	−.46**	−.44**	−.70**	−.28**	−.26**
07	−.25**	−.11	−.08	−.15	−.04	−.31	−.06	−.16	−.14	−.40	−.08	−.16
10	+.05*	+.29*	+.22*	+.25*	+.36*	+.09	+.14*	+.14*	+.26*	+.50*	+.42*	+.64*
13	−.25	+.29*	−.18	+.25*	+.26	+.19	+.14*	+.14*	+.16	+.20	−.18	+.04**
16	−.55**	−.11**	−.48**	+.05**	−.24**	+.19	−.06	−.16**	−.14**	.00**	−.28**	+.16*
19	+.15	+.29*	−.08	+.15	−.04	+.29*	−.16**	+.04	+.06	+.50*	+.12	+.14
22	+.65*	−.01	+.42*	+.25*	+.16*	+.29*	+.34*	+.34*	+.26*	+.20	+.32*	+.04
Mean monthly pressure	1004.05	1008.41	1004.98	1012.25	1015.34	1010.91	1014.86	1012.86	1011.24	1006.60	1007.78	1007.26
STATION J												
02	−0.36**	−0.18	−0.14	−0.41	−0.15	−0.34	−0.10	−0.15	−0.23	−0.21	−0.66**	−0.04
05	−.36**	−.38**	−.74**	−.61**	−.55**	−.54**	−.40**	−.45**	−.53**	−.31**	−.56	−.54**
08	+.04	−.08	−.14	+.09	−.15	−.14	−.30	−.15	+.17	+.09	+.14	+.26*
11	+.84*	+.42*	+.16*	+.49*	+.15*	+.06	−.10	+.25*	+.37*	+.49*	+.84*	+.06
14	−.06**	−.18**	−.04	+.39	+.05	+.26*	+.10*	+.05	−.03	−.11	−.16**	−.44**
17	−.06**	−.18**	−.24**	−.01**	−.15**	+.26*	−.10**	−.15**	−.63**	−.31**	+.24	−.04
20	+.14*	+.32*	+.46	+.09*	+.25	+.26*	+.10	+.25	+.37	+.09	+.54*	+.46*
23	−.16	+.22	+.66*	−.01	+.55*	+.16	+.80*	+.35*	+.47*	+.29*	−.36	+.26
Mean monthly pressure	1012.76	1009.68	1010.14	1017.81	1014.75	1014.34	1014.30	1014.45	1008.23	1009.31	1005.26	1010.24
STATION K												
02	+0.05	−0.36	−0.28	−0.25	−0.22	−0.37	−0.28	−0.30	−0.26	−0.39	−0.38	−0.44
05	−.75**	−.86**	−.58**	−.75**	−.72**	−.67**	−.48**	−.80**	−.76**	−.59**	−.58**	−.74**
08	−.15	−.16	+.22	+.05	+.08	−.07	+.12	.00	+.24*	+.01	+.22	−.04
11	+.65*	+.54*	+.42*	+.55*	+.28*	+.33*	+.42*	+.10	+.14	+.61*	+.52*	+.56*
14	−.55**	−.36**	−.18	+.05	+.08	+.13	+.12**	+.20*	−.06	−.19**	−.38**	−.44**
17	+.25	+.04	−.28**	−.45**	−.22**	+.03**	+.28*	−.10**	−.16**	−.09	+.02	+.06
20	+.55*	+.64*	+.22	+.25	+.28	+.23	+.02**	+.40	+.44*	+.51*	+.32*	+.66*
23	+.45	+.54	+.52*	+.55*	+.48*	+.43*	+.42*	+.50*	+.44*	+.11	+.22	+.36
Mean monthly pressure	1019.25	1017.36	1019.88	1018.65	1015.92	1019.07	1020.98	1019.90	1017.46	1018.19	1015.18	1019.54
STATION D												
00	+0.29	+0.25	+0.35	+0.26	0.00	+0.20	+0.21	+0.14	+0.02	+0.04	+0.09	+0.24
03	−.01**	−.15	−.35**	−.54**	−.70**	−.60**	−.49**	−.46**	−.48**	−.36**	−.41**	−.06
06	+.09	−.25**	−.15	−.34	−.30	−.30	−.19	−.26	−.38	−.06	−.11	−.26**
09	+.89*	+.45*	+.35*	+.16*	+.30*	.00	+.21*	+.14*	+.32*	+.44*	+.59*	+.44*
12	−.51	−.05	+.25	+.06	+.30*	+.10*	+.11	+.04	+.22	−.06	−.11	−.36
15	−.01**	−.75**	−.65**	−.34**	.00**	.00**	−.19**	−.06**	−.28**	−.56**	−.61**	−.56**
18	−.31	−.05	−.25	−.04	.00**	.00**	−.19**	−.06**	+.02	+.14	+.09	+.04
21	+.59*	+.55*	+.45*	+.76*	+.40*	+.60*	+.51*	+.54*	+.52*	+.34*	+.49*	+.54*
Mean monthly pressure	1014.61	1014.85	1008.55	1016.34	1014.40	1018.30	1021.99	1019.66	1018.18	1016.06	1018.11	1016.16

TABLE 2.—*Mean monthly pressures (mb.) and mean departures from the mean monthly pressures. * denotes maxima of DVMP, ** denote minima of DVMP. Time is in Local Standard (Zone) Time*—Continued

Time	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						STATION H						
01	−0.28	+0.11	−0.14	−0.26	−0.20	−0.14	−0.30	−0.21	−0.06	−0.15	−0.41	−0.36
04	−.58**	−.59**	−.74**	−.76**	−.50**	−.54**	−.50**	−.61**	−.46**	−.45**	−.61**	−.46**
07	−.18	+.21	+.36	+.34	−.30	+.26	+.20	+.19	+.24	+.35	+.29	+.34
10	+.92*	+.81*	+.96*	+.84*	+.40*	+.46*	+.60*	+.69*	+.74*	+.75*	+1.19*	+1.24*
13	−.38**	−.49	+.06	+.14	+.30	+.16	+.30	+.19	+.04	−.35	−.41	−.66**
16	−.18	−.79**	−.84**	−.56**	−.30**	−.34**	−.30**	−.31**	−.46**	−.65**	−.51**	−.46
19	+.12	+.21	−.04	−.16	.00	−.24	−.30**	−.21	−.36	+.05	+.19	+.24*
22	+.22*	+.51*	+.36*	+.44*	+.60*	+.36*	+.30*	+.29*	+.34*	+.45*	+.29*	+.14
Mean monthly pressure	1020.08	1016.49	1015.34	1016.26	1014.40	1016.44	1018.90	1017.21	1017.46	1017.35	1017.31	1019.06
						STATION E						
00	+0.11	+0.34	+0.24	+0.24	+0.35	+0.25	+0.32	+0.44	+0.26	+0.15	+0.32	+0.25
03	−.19	−.36	−.66**	−.66**	−.85**	−.65**	−.58**	−.46**	−.54**	−.65**	−.38	−.15
06	−.59**	−.96**	−.56	−.56	−.45	−.45	−.38	−.26	−.44	−.55	−.48**	−.45**
09	+.61*	+.54	+.44	+.44	+.25	+.25	+.22	+.34	+.36	+.55*	+.62*	+.65*
12	+.41	+.64*	+.64*	+.54*	+.55*	+.45*	+.42*	+.44*	+.46*	+.45	+.32	+.25
15	−.69**	−.66**	−.46**	−.26**	−.05	+.05	−.08	−.16	−.44**	−.45**	−.68**	−.75**
18	+.01	−.16	−.16	−.26**	−.25**	−.35**	−.38**	−.36**	−.24	−.05	−.18	−.25
21	+.31*	+.64*	+.54*	+.54*	+.45*	+.45*	+.42*	+.64*	+.56*	+.55*	+.42*	+.45*
Mean monthly pressure	1022.69	1018.26	1015.46	1020.16	1019.05	1022.35	1024.98	1023.06	1020.94	1019.85	1021.28	1018.85

During World War II, the German submarine menace forced the OVS to be more transient than stationary. Under the circumstances, it is impossible completely to isolate temporal from spatial variations; therefore, OVS observations taken prior to 1946 were excluded from the computations. The OVS included are those for which at least three years of postwar records per month are available. The final selection of data is shown in table 1. Certain intervals within the study period have been excluded, as shown by the footnotes to the table; in some cases, there were obvious tabulation errors; in others, the stations were temporarily abandoned for one reason or another.

Eight mean pressures were computed for each month for each OVS, for 0000 GMT and each 3 hours thereafter. Thus, a total of 96 mean pressures was calculated for each OVS. The last column of table 1 gives the average number of individual observations used in constructing these 96 means.

3. DAILY VARIATION OF MEAN PRESSURE

Table 2 gives, for each OVS, the mean monthly pressures for each month of the year and the differences between the 3-hourly mean pressures and the mean monthly pressures (hereafter called "departures"). In this table, the time has been converted to Local Standard (Zone) Time. The tables are arranged according to decreasing latitude of the OVS.

Northernmost stations.—Stations M (66° N.) and A (62° N.) show erratic and complicated month-to-month changes of the daily variation of mean pressure (DVMP). At M, the times of the maxima and minima wander, in an apparently unsystematic fashion, from hour to hour during the course of the year Seven months show double maxima, five display a single maximum.

At A, while less complicated, the annual course of the DVMP is still far from systematic. All months, except December, show a minimum at 0400 LST. All months, except July, display an evening maximum at 1900 or 2200 LST. Most months show another maximum and minimum at hours varying through the year.

Moderately northward stations.—The annual changes of the DVMP at B (56.5° N.) and C (52.8° N.) are complicated but appear to be somewhat more systematic than those found at the northernmost stations. Station B (table 2) shows a definite tendency for the primary maximum to occur at 2100 LST. The time of the primary minimum appears to oscillate between 0300 and 0600 LST. The hours of the secondary maxima and minima vary erratically from month to month. Some preference is found, however, for a secondary maximum (minimum) at 0900 (1500) LST. The double structure vanishes in July and August.

At C, maxima occur fairly consistently at 1000 and 2200 LST. Minima tend to occur at 0400 and 1600 LST, the former hour being preferred for the primary minimum. The double structure disappears only in June.

Station J (52.5° N.) shows less erratic behavior than any of the four stations discussed thus far. A morning maximum appears at 1100 LST in nine months. The evening maximum occurs at 2000 LST in six months, at 2300 LST during the other six months. The primary maximum appears with about equal frequency in the morning and evening. Minima occur at 0500 and 1700 LST in almost all months, the former hour being strongly preferred for the primary minimum. The double structure vanishes only in June.

The three stations in this group show, generally, larger departures from the mean monthly pressures than do the two "northernmost" stations.

Moderately southward stations.—Stations K (45° N.) and D (44° N.) show generally larger departures than do the stations previously discussed. At K (table 2), the primary minimum occurs at 0500 LST in all months. The secondary minimum occurs at 1700 LST in the months March through June, August, and September; from

October through February it appears at 1400 LST. A morning maximum is found at 1100 LST in all months except August and September. A nocturnal maximum appears at 2300 LST in the months March through September, and at 2000 LST during the months October through February. An interesting feature is that the afternoon minimum and the nocturnal maximum occur three hours earlier during the fall and winter months than during the remainder of the year. On careful inspection, a similar phenomenon is observed at J.

Station D exhibits a nocturnal maximum at 2100 LST. This is the primary maximum in all months except October, November, and January. A morning maximum is found at 0900 LST in all months except June. Minima consistently occur at 0300 and 1500 LST, the primary minimum occuring at the latter hour from October through March, at the former hour during the remainder of the year.

Southernmost stations.—The month-to-month changes of the DVMP at H (36.7° N.) and E (35° N.) are fairly systematic. Station H (table 2) shows an 0400 LST minimum in all months. A daytime minimum occurs at 1600 LST from February through November; in December and January it appears at 1300 LST. The daytime minimum tends to be the secondary one in the warm months, the primary one in the cold months. A 1000 LST maximum occurs in all months. Another maximum is found at 2200 LST in all months except December.

Station E shows a 2100 LST maximum in all months. A morning maximum occurs at 1200 LST from February through September, and is displaced to 0900 LST during the rest of the year. Neither morning nor evening is preferred for the primary maximum; in fact, five months have equal strength of the two maxima. A nocturnal minimum is found at 0300 LST from March through October, three hours later during the remainder of the year. It is the primary minimum except in November, December, and January. A second minimum occurs at 1800 LST from May through August, three hours earlier in all other months.

Summary.—The data show that the month-to-month changes of the DVMP tend to become more systematic as the latitude decreases. It is also clear that, generally, the magnitudes of the departures become greater with decreasing latitude.

Possibly this latitudinal variation of the departures can partially explain the erratic annual variations of the DVMP in the higher latitudes. Results of statistical studies of this type are subject to sampling and round-off errors. In these computations, the same absolute error will, on the average, be a larger percentage error in the higher latitudes than in the lower ones. The higher percentage error in the higher latitudes may then be a partial explanation of the relatively greater erratic behavior of the DVMP in higher latitudes.

Diurnal variation of mean annual pressure.—Table 3 summarizes the mean annual pressures and the mean annual departures for each observation hour at each OVS. Time is given in GMT. The bottom row gives the correction in hours, which will convert GMT to LST.

TABLE 3.—*Mean annual pressures (mb.) and mean annual departures from the mean annual pressures. *denotes maxima of DVMP, **denotes minima of DVMP. Time is in* GMT. *Δt is the correction, in hours, which will convert* GMT *to* LST

Time	Station								
	M	A	B	C	J	K	D	H	E
00	−0.01	+0.33*	+0.29*	+0.27*	+0.29*	+0.39*	+0.53*	−0.03	+0.48*
03	−.21	−.02	+.06	−.08	−.23	−.29	+.16	+.35*	+.28
06	−.33**	−.35**	−.27**	−.38**	−.51**	−.67**	−.37**	−.19	−.53**
09	−.02	−.13	−.22	−.16	−.01	+.04	−.21	−.58**	−.49
12	+.07*	+.18	+.09*	+.29*	+.33*	+.44*	+.36*	+.19	+.43
15	+.04**	+.21*	+.08	+.08	−.01	−.12	.00	+.79*	+.46*
18	+.34*	+.04	−.12**	−.16**	−.10	−.15**	−.42**	−.08	−.40**
21	+.09	−.33**	+.10	+.11	+.27	+.37	−.07	−.46**	−.23
Mean annual pressure	1006.64	1003.76	1008.68	1009.81	1011.19	1018.52	1016.44	1017.14	1020.48
Δt	0	−2	−3	−2	−1	−1	−3	−5	−3

Except at M, there is a marked double structure of the DVMP. M being neglected, all stations have minima at the observation hours closest to 0400 and 1600 LST. All but M and E have maxima at the observation hours closest to 1000 and 2200 LST. At E, one maximum is found at the observation hour closest to 2200 LST, another at 1200 LST; however, the departure at 1200 LST is only 0.03 mb. greater than that at 0900 LST. Thus, the disagreement with the pattern at the other OVS is not great.

Of considerable interest is the fact that only H (M again being neglected) shows a pronounced forenoon maximum. At A, B, and D, well-developed primary maxima occur in the evening. At C, J, K, and E, the two maxima are about equal in intensity.

Pronounced primary minima are found at the observation hour closest to 0400 LST at B, C, J, and K. Other stations showing clearly defined primary minima at this time, although not as pronounced, are H and E. At A and D, the two minima are about equal in intensity. No station shows a strongly marked afternoon minimum, and only D shows a tendency for a primary minimum in the afternoon.

4. THREE-HOUR MEAN-PRESSURE TENDENCIES

Table 4 gives, for each OVS, the mean 3-hour mean-pressure tendencies (hereafter called "tendencies") for each observation hour of each month. Times in these tables are Greenwich Mean Time. The tendencies are computed as the net change of the mean pressure during the 3-hour period ending at the stated observation hour. Numerical values are given in units and tenths of millibars.

As expected from the preceding discussion, the magnitude of the tendency is clearly dependent on latitude, larger magnitudes being found at lower latitudes. Variations with month of the year and time of day are also in evidence. These variations, however, are more complicated than the latitudinal ones and, in some cases, appear to be almost random. The annual variation seems to favor smaller tendencies in the warm months and larger

TABLE 4.—*3-hour mean-pressure tendencies in units and tenths of millibars*

Time (GMT)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
STATION M												
00	−04	+01	+01	−07	+01	−01	+01	−02	−01	−01	+08	−06
03	+04	−03	−01	00	−06	−03	−04	−02	−03	−01	−04	00
06	−01	−04	−01	+02	−02	00	−01	−01	−02	−01	−02	−01
09	+04	+01	+02	+04	+03	+02	+01	+03	+03	+03	+03	+06
12	00	+03	+02	+02	+02	+01	+03	+01	−01	00	−03	00
15	−02	00	00	+02	+01	+01	+01	+02	−01	−02	−02	−01
18	−01	+01	−03	00	−01	00	−01	−01	00	+02	+01	+01
21	00	+01	00	−03	+02	00	00	00	+05	00	−01	+01
STATION A												
00	+01	−08	−04	−03	+03	+06	−01	+06	+05	+01	+05	−01
03	−03	−03	−01	−03	−01	−04	−01	−02	−02	−04	−05	−11
06	−03	−04	−05	−04	−04	−04	−03	−07	−04	−02	−03	+03
09	+01	+01	+01	+04	+03	+01	+02	+01	+02	+02	+04	+02
12	+04	+07	+06	+05	+02	+03	+04	+02	+01	+03	−03	+08
15	+01	+02	+04	+02	00	+01	00	+02	−02	−02	00	−04
18	−05	+06	−02	−03	−02	−03	−01	−02	−02	00	−01	+02
21	+04	+04	+02	+02	+02	00	00	00	+01	+03	+05	+01
STATION B												
00	+02	00	+03	+03	+01	+04	+05	00	+01	+05	−02	−03
03	−03	−02	−03	−03	−01	−02	−02	−01	−02	−04	+02	−06
06	−04	−05	−05	−04	−03	−04	−04	−04	−03	−03	00	−03
09	−01	+01	+02	−01	+01	+01	−01	−01	+01	+01	00	−02
12	+04	+07	+04	+03	+03	+01	+02	+03	+03	+03	+03	+03
15	00	00	00	+01	00	00	00	+01	+01	−01	−03	+01
18	−02	−04	−03	−02	−02	−01	00	00	−03	−03	−03	−01
21	+04	+03	+02	+03	+01	+01	00	+02	+01	+03	+03	+06
STATION C												
00	+05	−03	+05	+01	+02	00	+05	+03	+02	−03	+02	−01
03	−05	−02	00	−04	−04	−05	−03	−02	−04	−05	−04	−03
06	−01	−02	−07	−05	00	−03	−04	−06	−03	−04	−02	00
09	−03	+03	+02	+05	+02	+02	+03	+03	+03	+03	+02	+01
12	+03	+04	+03	+04	+04	+04	+02	+03	+04	+09	+05	+08
15	−03	00	−04	00	−01	+01	00	00	−01	−03	−06	−06
18	−03	−04	−03	−02	−05	00	−02	−03	−03	−02	−01	+01
21	+07	+04	+04	+01	+02	+01	−01	+02	+02	+05	+04	00
STATION J												
00	−03	−01	+02	−01	+03	−01	+07	+01	+01	+02	−09	−02
03	−02	−04	−08	−04	−07	−05	−09	−05	−07	−05	−03	−03
06	00	−02	−06	−02	−04	−02	−03	−03	−03	−01	+01	−05
09	+04	+03	+06	+07	+04	+04	+01	+03	+07	+04	+07	+08
12	+08	+05	+03	+04	+03	+02	+02	+04	+02	+04	+07	+02
15	−09	−06	−02	−01	−01	+02	+02	−02	−04	−06	−10	−05
18	00	00	−02	−04	−02	00	−02	−02	−06	−02	+04	+04
21	+02	+05	+07	+01	+04	00	+02	+02	+10	+04	+03	+05
STATION K												
00	−01	−01	+03	+03	+02	+02	+04	+01	00	−04	−01	−03
03	−04	−09	−08	−08	−07	−08	−07	−08	−07	−05	−06	−08
06	−08	−05	−03	−05	−05	−03	−02	−05	−05	−02	−02	−03
09	+06	+07	+08	+08	+08	+06	+06	+08	+10	+06	+08	+07
12	+08	+07	+02	+05	+02	+04	+03	+01	−01	+06	+03	+06
15	−12	−09	−06	−05	−02	−02	−03	+01	−02	−08	−09	−10
18	+03	+04	−01	−05	−03	−01	+02	−03	−01	+01	+04	+05
21	+08	+06	+05	+07	+05	+02	−03	+05	+06	+06	+03	+06
STATION D												
00	+09	+06	+07	+08	+04	+06	+07	+06	+05	+02	+04	+05
03	−03	−03	−01	−05	−04	−04	−03	−04	−05	−03	−04	−03
06	−03	−04	−07	−08	−07	+08	−07	−06	−05	−04	−05	−03
09	+01	−01	+02	+02	+04	+03	+03	+02	+01	+03	+03	−02
12	+08	+07	+05	+05	+06	+03	+04	+04	+07	+05	+07	+07
15	−14	−05	−01	−01	00	+01	−01	−01	−01	−05	−07	−08
18	−05	−07	−09	+04	−03	−01	−03	−01	−05	−05	−05	−02
21	+07	+07	+04	+03	+04	00	00	00	+03	+07	+07	+06
STATION H												
00	+03	+10	+08	+04	+03	+01	00	+01	+01	+07	+07	+07
03	+01	+03	+04	+06	+06	+06	+06	+05	+07	+04	+01	−01
06	−05	−04	−05	−07	−08	−05	−06	−05	−04	−06	−07	−05
09	−03	−07	−06	−05	−03	−04	−02	−04	−04	−03	−02	−01
12	+08	+08	+11	+11	+02	+08	+07	+08	+07	+08	+09	+08
15	+07	+06	+06	+05	+07	+02	+04	+05	+05	+04	+09	+09
18	−13	−13	−09	−07	−01	−03	−03	−05	−07	−11	−16	−19
21	+02	−03	−09	−07	−06	−05	−06	−05	−05	−03	−01	+02

TABLE 4.—*3-hour mean-pressure tendencies in units and tenths of millibars*—Continued

Time (GMT)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
STATION E												
00	+01	+03	+04	+06	+06	+06	+06	+05	+07	+04	+01	−01
03	−05	−04	−05	−07	−08	−05	−06	−05	−04	−06	−07	−05
06	−03	−07	−06	−05	−03	−04	−02	−04	−04	−03	−02	−01
09	+08	+08	+11	+11	+02	+08	+07	+08	+07	+08	+09	+08
12	+07	+06	+06	+05	+07	+02	+04	+05	+05	+04	+09	+09
15	−13	−13	−09	−07	−01	−03	−03	−05	−07	−11	−16	−19
18	+02	−03	−09	−07	−06	−05	−06	−05	−05	−03	−01	+02
21	+03	+10	+08	+04	+03	+01	00	+01	+01	+07	+07	+07

ones in the cold months; this, however, is a gross generalization and several of the tendencies do not conform with it.

From the synoptic point of view, the tendencies in the vicinity of the "northernmost" and "moderately northward" stations are probably negligible in comparison to the error made in correcting tendencies reported by moving ships. If one considers the strong horizontal pressure gradients usually observed in the vicinity of the "moderately southward" stations, it seems reasonable to suspect that the tendencies in the regions of these stations can also be neglected with respect to the motion error.

Stations H and E, the "southernmost" stations, show generally larger tendencies, than do the other OVS. Also, these stations are in areas where weak horizontal pressure gradients are more frequently observed. For these two reasons, the tendencies in the vicinity of these stations are more likely to be important in comparison with the error due to correction for ship motion.

Table 5 is presented to complete the overall picture of the 3-hour pressure tendencies. It gives, for each observation hour at each station, the tendency as obtained from the mean annual pressures.

For comparison of the tendencies at the OVS with those at continental stations at corresponding latitudes, the reader may utilize data published by the U. S. Weather Bureau [14, 15].

5. HARMONIC ANALYSIS OF THE DIURNAL VARIATION OF MEAN PRESSURE

In recent years there has been a considerable revival of interest in pressure oscillations and harmonic analysis of

TABLE 5.—*3-hour mean annual pressure tendencies in units and tenths of millibars. Time is in* GMT

Time	Station								
	M	A	B	C	J	K	D	H	E
00	−01	+06	+02	+02	+00	+00	+06	+04	+07
03	−02	−04	−02	−04	−05	−07	−04	+04	−02
06	−01	−03	−03	−03	−03	−04	−05	−05	−08
09	+03	+02	+01	+02	+05	+07	+02	−04	+00
12	+01	+03	+03	+05	+03	+04	+06	+08	+09
15	−00	+00	−00	−02	−03	−06	−04	+06	+00
18	+03	−02	−02	−02	−01	−00	−04	−09	−09
21	−03	−03	+02	+03	+04	+05	+04	−04	+02

the DVMP (for examples, see [4, 6, 7, 8, 12, 13, 16]). Included among these new works has been a discussion of the magnitudes of the harmonic constants under a purely oceanic regime by Haurwitz [8]. However, to the knowledge of the writers, no one has utilized the OVS data for computation of these harmonic constants. It was therefore deemed worthwhile to extend this investigation to include computations of the amplitudes and phase angles of the first three harmonics of the DVMP. Computations were made for all months of the year at each station, the results being summarized in tables 6 through 11.

In performance of such analyses, the generally preferred procedure, which was also employed here, is use of a sine series in the form

$$p=p_0+\sum_n p_n \sin\left(\frac{n\pi}{12}t+\phi_n\right),$$

where p is the mean pressure at time t, p_0 the pressure averaged over all hours and a complete month, n the harmonic, p_n the amplitude of the n'th harmonic, t the time in hours on a 24-hour clock, and ϕ_n is the phase angle, in radians of the n'th harmonic. Evaulation of p_n and ϕ_n is straightforward but tedious. For computational details, the reader is referred to Brooks and Carruthers [2].

The values of ϕ_n, given in tables 7, 9, 11, and 12 have been converted to local mean (*not* standard) time in hours. For the second and third harmonics, the times shown are those of the first maximum. The p_n, given in tables 6, 8, 10, and 12 are in millibars.

The primary objective here is to make these harmonic constants available to investigators primarily interested in pressure oscillations. However, it is of some interest briefly to compare these results with those of other empirical studies and with theoretical expectations.

First harmonic.—Most writers (for examples, see [4, 8, 9, 10, 16]) feel that the 24-hour oscillation is almost entirely due to the alternate heating and cooling of the air during the course of the day. If so, strong local, seasonal, and synoptic effects would be expected in p_1 and ϕ_1, and there is some confusion in the literature concerning representative values of ϕ_1. Chapman [4] states that the first harmonic has its maximum at about local noon. Humphreys [9] claims, without producing evidence, that at low elevations the maximum of the first harmonic occurs during the coldest hours, while at high elevations it is found during the warmest hours. Bartels [1] found the maximum near 0800 local time at Washington, D. C. At Bermuda, Haurwitz [8] found the maximum to be around local noon during the summer, between 1000 and 1100 local time during the winter.

The OVS show (table 7) large annual and spatial variations of ϕ_1. There is no evidence to support the choice of a particular ϕ_1 as representative of all months and/or all locations considered. This is consistent with the thoughts of Jenkins [10], who states that the first harmonic

TABLE 6.—*Amplitude (mb) of the 24-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	0.25	0.27	0.17	0.53	0.28	0.21	0.22	0.26	0.16	0.08	0.23	0.29
A	.16	.41	.46	.45	.16	.13	.24	.23	.12	.16	.19	.50
B	.25	.26	.18	.25	.10	.15	.21	.26	.11	.11	.14	.39
C	.33	.25	.22	.32	.17	.11	.08	.14	.16	.42	.05	.04
J	.32	.12	.33	.40	.25	.38	.32	.19	.05	.07	.48	.18
K	.23	.39	.09	.16	.22	.32	.14	.34	.24	.26	.18	.33
D	.46	.20	.11	.25	.28	.29	.11	.19	.05	.06	.05	.26
H	.18	.16	.26	.26	.19	.17	.28	.26	.24	.17	.24	.25
E	.04	.16	.20	.21	.27	.23	.15	.08	.11	.20	.02	.11

TABLE 7.—*Local Mean Time (hours) of the maximum of the 24-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	22.9	20.6	15.1	15.3	19.2	17.4	18.2	17.0	22.6	16.8	3.7	8.5
A	16.9	15.3	15.6	15.2	17.8	20.1	14.9	20.5	.8	19.1	23.3	14.8
B	19.3	15.4	16.5	19.5	15.7	20.8	20.9	18.4	16.6	21.7	7.0	17.6
C	23.4	14.1	.6	16.6	11.8	16.5	16.3	18.1	15.8	15.5	19.6	15.9
J	12.5	17.4	19.4	13.5	19.0	15.7	20.4	17.9	18.6	11.6	13.7	18.7
K	20.4	18.4	7.2	16.5	17.3	16.8	11.4	17.8	18.2	15.8	15.6	17.8
D	3.3	1.0	2.4	20.2	15.6	18.6	19.2	18.7	11.7	23.4	.6	18.4
H	12.1	3.6	9.4	10.8	16.6	10.6	11.2	11.6	8.9	6.6	10.4	9.2
E	12.5	17.8	15.3	15.3	15.5	15.3	15.7	17.8	16.7	15.5	2.5	3.8

varies between oceans and continents, with latitude, and over the ocean between the major divisions thereof.

The amplitude of the first harmonic (p_1) is, according to Chapman [4], larger in summer than in winter. Bartels [1] and Haurwitz [8] have verified this with data for Washington and Bermuda, respectively. At the OVS (table 6), the months of maximum and minimum p_1 vary considerably from station to station. At all of the stations, there are several months of maximum and minimum p_1, so that no simple seasonal variation may be specified.

Second harmonic.—It is generally accepted (for examples, see [4, 7, 12, 16]) that the 12-hour pressure oscillation is produced by an interaction of the 12-hour component of the daily variation of mean air temperature and the 12-hour component of the solar tidal potential.

TABLE 8.—*Amplitude (mb) of the 12-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	0.20	0.15	0.16	0.13	0.21	0.07	0.13	0.06	0.21	0.11	0.18	0.18
A	.26	.16	.16	.19	.26	.29	.13	.30	.24	.24	.22	.32
B	.24	.33	.29	.22	.17	.19	.20	.13	.20	.31	.10	.25
C	.30	.20	.37	.28	.25	.18	.25	.29	.30	.35	.33	.28
J	.31	.34	.47	.28	.26	.13	.30	.30	.54	.37	.43	.38
K	.57	.56	.50	.59	.44	.36	.41	.40	.45	.36	.46	.52
D	.63	.49	.52	.48	.38	.34	.39	.33	.43	.45	.53	.40
H	.53	.71	.73	.66	.46	.43	.43	.48	.50	.62	.73	.70
E	.53	.77	.66	.61	.57	.50	.50	.55	.59	.63	.62	.58

TABLE 9.—*Local Mean Time (hours) of the first maximum of the 12-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	9.1	0.4	0.7	7.3	11.6	10.6	11.7	11.2	10.6	10.0	11.8	9.4
A	10.3	8.7	11.1	10.0	10.0	10.9	10.6	11.2	10.4	9.6	9.0	8.6
B	9.6	10.1	9.5	9.9	9.9	9.8	10.3	10.2	10.0	9.3	9.0	8.2
C	9.6	9.4	10.1	9.4	9.8	9.5	10.4	10.3	9.7	9.3	9.2	9.2
J	9.7	9.8	10.2	10.4	10.4	10.0	11.0	10.4	10.0	10.1	8.6	8.9
K	10.1	9.8	10.0	10.5	10.4	10.4	10.6	10.3	9.8	10.5	9.4	9.6
D	9.3	9.8	10.3	10.0	10.1	10.2	10.2	10.1	10.0	9.2	9.3	10.2
H	9.5	9.7	10.0	10.1	10.7	10.3	10.4	10.3	10.4	9.6	9.4	9.1
E	9.9	10.3	10.0	10.1	10.3	10.4	10.4	10.3	10.0	9.8	9.9	9.8

The resulting oscillation is supposedly greatly amplified by a resonance phenomenon. It has been shown [11] that the solar semidiurnal tidal potential (SSTP) exhibits maxima of almost equal strength in March and October, a primary minimum in June, and a secondary minimum in December. The SSTP is also strongly dependent on latitude, being largest at the equator and decreasing poleward in each hemisphere.

Spar [13,] in an empirical study, found the strongest variation of p_2 over the United States to be with latitude. He found a seasonal variation in fair agreement with that discerned by Hann [5] for Montevideo, Uruguay.

It is possible to identify, at almost all of the OVS (table 8), maxima and minima which appear to correspond to the maxima and minima of the SSTP. However, as was the case in the studies by Spar and Hann, these maxima and minima are sometimes displaced as much as two months relative to each other. Inspection of table 8 shows that the annual variation of p_2 is limited to two maxima and minima only at the two "southernmost" stations, the others showing additional maxima and minima which do not correspond to extremes of the SSTP.

Possible worthiness of further investigation of these additional maxima and minima must be left to the judgment of investigators more familiar with the results of p_2 computations. No attempt has been made here to evaluate the thermal effects on p_2. It is possible that further investigation would show many of the discrepancies between our results and the annual variation of the SSTP to be explicable on thermal grounds.

Time-space sections of p_2 were constructed along curves joining various combinations of the OVS. Values of p_2 for February and August were picked off these sections, plotted on maps, and subjected to isopleth analysis. The results are displayed in figures 1 and 2. These charts show strong meridional gradients of p_2 which apparently correspond to the latitudinal variations of the SSTP. Some fairly strong zonal gradients are also indicated. Also of interest is the marked change in the isopleth pattern between February and August. These features appear to be worthy of investigation by authorities in the field of pressure oscillations.

The phase angle of the second harmonic of the DVMP is relatively uniform over the earth's surface [4]. Almost everywhere, the first maximum occurs about 1000 local time. Chapman [3] has presented a theoretical explanation of this worldwide relative uniformity of ϕ_2. His theory, however, is far from complete, and there has been some conflicting empirical evidence [8, 12].

Spar's result for the United States [13] showed ϕ_2 to be latest in June and earliest in January. Haurwitz [8] and Chapman [4] found the annual variations of ϕ_2 at Bermuda and Kunamoto (33° N., 131° E.), respectively, to be similar to those found by Spar.

Table 9 shows that the annual variations of ϕ_2 differ considerably from one OVS to the next. The only consistency among stations appears to be a tendency for latest ϕ_2 to occur during summer and for earliest ϕ_2 to occur around November and December. Only M does not fit this pattern.

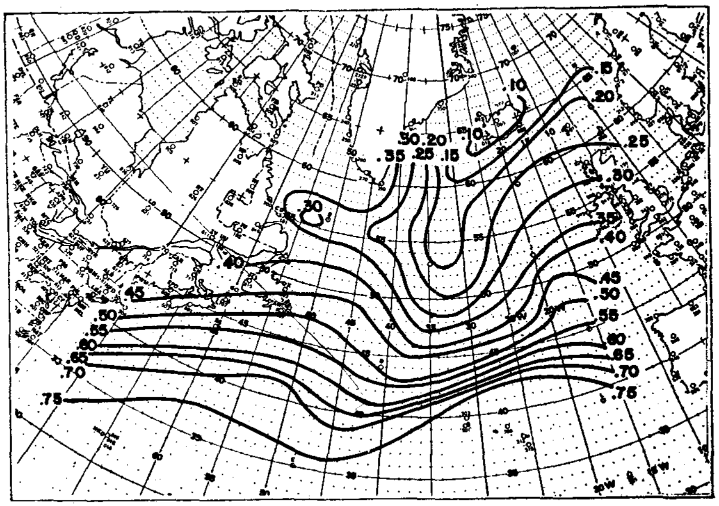

FIGURE 1.—Amplitude (mb.) of 12-hour harmonic of daily variation of mean pressure (DVMP) in February.

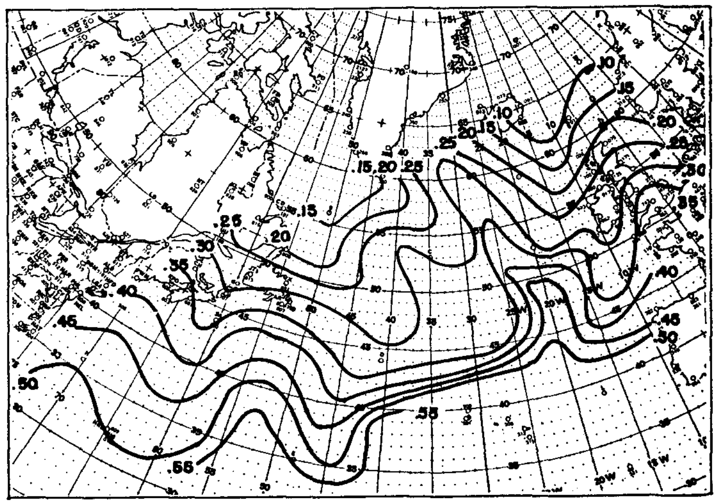

FIGURE 2.—Amplitude (mb.) of 12-hour harmonic of DVMP in August.

Third harmonic.—The 8-hour harmonic of the DVMP has been subject to less investigation than have the first two harmonics. The sun's tidal action has no appreciable component with an 8-hour period [4]. Therefore, the 8-hour pressure oscillation is usually assumed to be entirely a thermal phenomenon. Chapman [4] claims that p_3 resembles, in geographical and seasonal variation, the third harmonic of the daily variation of mean air temperature. Haurwitz [7] indicates that resonance also plays a small part in amplifying the thermally produced 8-hour oscillation.

There is evidence [1, 4, 8] that the 8-hour oscillation is largest in winter, has opposite phases north and south of the equator, and has opposite phases in summer and winter. Humphreys [9] states that p_3 reaches maxima at 30° latitude in each hemisphere, is zero at the equator,

TABLE 10.—*Amplitude (mb) of the 8-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	0.12	0.04	0.04	0.04	0.08	0.04	0.06	0.03	0.00	0.08	0.22	0.09
A	.10	.85	.09	.04	.06	.10	.07	.11	.07	.02	.15	.08
B	.07	.10	.04	.05	.02	.06	.06	.04	.03	.04	.15	.09
C	.15	.10	.08	.05	.03	.26	.11	.04	.04	.16	.08	.17
J	.22	.12	.04	.02	.13	.06	.19	.03	.10	.04	.27	.17
K	.30	.16	.07	.02	.08	.07	.09	.12	.11	.18	.16	.19
D	.15	.14	.05	.07	.07	.14	.11	.10	.05	.09	.11	.15
H	.23	.19	.04	.09	.13	.14	.12	.08	.09	.07	.21	.32
E	.31	.29	.09	.03	.14	.14	.13	.13	.07	.10	.17	.20

TABLE 11.—*Local Mean Time (hours) of the first maximum of the 8-hour harmonic of the DVMP*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M	3.4	2.6	7.1	3.9	7.9	6.3	7.5	0.2	6.7	2.5	7.2	3.3
A	3.9	7.5	2.4	6.7	6.3	6.0	1.5	6.8	6.7	4.7	6.2	7.7
B	2.6	1.8	4.5	3.5	1.2	5.9	6.1	1.4	4.2	4.4	.3	2.9
C	3.7	2.8	.6	7.2	4.2	3.7	6.5	7.2	5.2	2.2	1.9	2.2
J	2.7	2.9	6.8	7.2	6.5	6.2	6.5	4.3	5.0	3.3	2.4	2.3
K	2.4	2.2	.1	6.1	6.3	6.3	6.2	7.1	7.9	2.9	1.7	2.4
D	1.6	2.7	4.0	5.9	5.9	5.6	6.9	6.7	3.6	2.4	1.9	1.9
H	1.6	1.9	2.0	7.9	5.3	6.0	6.7	7.7	.0	1.6	2.1	2.0
E	2.3	2.5	3.2	4.4	6.3	6.2	6.1	5.8	3.9	2.3	2.0	2.3

and that during the winter the first maximum occurs at 0200 local time.

The OVS data (tables 10 and 11) appear to verify the tendency for larger p_3 during winter than summer. There are departures from this pattern, but much of this non-conformity can probably be attributed to round-off and sampling errors. The 0.85-mb. value for p_3, found at A in February, must obviously be considered an error.

There is some degree of agreement between the results of this study and the 180-degree, winter to summer, change of phase of the third harmonic found by others [1, 4]. (An 180-degree change of phase would constitute a 4-hour change in ϕ_3). Stations A and M, however, show several, rather than a single, 180-degree change of phase during the course of the year. A winter ϕ_3 of approximately 0200 local time, consistent with the findings of Humphreys [9], appears at B, D, E, H, J, and K.

A time section along the curve joining A, C, D, and E (not reproduced here) shows no evidence of the latitudinal variation of p_3 suggested by Humphreys.

Analysis of mean annual pressure.—Table 12 gives the harmonic constants for the first three harmonics of the diurnal variation of mean annual pressure.

The amplitude of the first harmonic (p_1) is apparently not a function of the latitude. The data show a tendency for larger p_1 to occur closer to land masses. (A rough isopleth analysis indicates a trough in the p_1 field which extends from the vicinity of A to the region just to the west of E.) The phase angle of the first harmonic (ϕ_1) appears to have complicated variations with both latitude and longitude. It is interesting to note that the western stations (B, D, E, and H) have ϕ_1's which roughly coincide with maxima of the second harmonic, while the eastern stations (M, A, C, J, and K) have ϕ_1's which roughly coincide with minima of the second harmonic.

TABLE 12.—*Harmonic constants for the first 3 harmonics of the annual DVMP. Phase angles are tabulated as the Local Mean Time (hours) of the first maximum*

Station	p_1	ϕ_1	p_2	ϕ_2	p_3	ϕ_3
M	0.23	17.4	0.06	9.4	0.11	2.1
A	.12	14.7	.26	11.0	.14	6.6
B	.14	23.5	.20	9.2	.02	2.6
C	.13	16.1	.28	9.7	.03	2.5
J	.19	16.8	.33	10.0	.03	1.9
K	.22	17.2	.46	10.0	.06	1.9
D	.10	22.0	.44	9.8	.02	2.0
H	.17	10.6	.56	10.0	.07	1.8
E	.11	10.1	.59	10.1	.05	2.7

The latitudinal variation of p_2 is well pronounced. South of 55° N., no longitudinal variation is indicated. North of 55° N., the value at M of 0.06 mb. suggests an appreciable longitudinal variation in p_2. The exact, or even approximate, form of this variation cannot be determined on the basis of the data presented here. ϕ_2, on the whole, appears to have no strong spatial variations. The importance of the value of 11.0 LMT at A is difficult to estimate.

All stations except A show ϕ_3 in the vicinity of 0200 LMT. The value of 6.6 LMT at A is approximately 180 degrees out of phase with the other values. The largest values of p_3 occur to the northeast. Except for an immediate decrease to the south and west of the region of A and M, it is difficult to determine spatial variations of p_3.

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REFERENCES

1. J. Bartels, "Tides in the Atmosphere," *Scientific Monthly*, vol. 35, 1932, pp. 110–130.
2. C. E. P. Brooks, and N. Carruthers, *Handbook of Statistical Methods in Meteorology*, H. M. Stationery Office, London, 1953, 412 pp.
3. S. Chapman, "The Semidiurnal Oscillation of the Atmosphere," *Quarterly Journal of the Royal Meteorological Society*, vol. 50, 1924, pp. 165–193.
4. S. Chapman, "Atmospheric Tides and Oscillations," *Compendium of Meteorology*, American Meteorological Society, Boston, 1951, pp. 510–530.
5. J. Hann "Die jährliche Periode der halbtägigen Luftdruckschwankung," *Sitzungs-Berichte, Akademie der Wissenschaften, Wien*, IIa, vol. 127, 1918, pp. 263–365.

6. M. F. Harris, "Pressure-Change Theory and the Daily Barometric Wave," *Journal of Meteorology*, vol. 12, No. 4, Aug. 1955, pp. 394–404.
7. B. Haurwitz, "Harmonic Analysis of the Diurnal Variations of Pressure and Temperature Aloft in the Eastern Caribbean," *Bulletin of the American Meteorological Society*, vol. 28, No. 7, Sept., 1947, pp. 319–323.
8. B. Haurwitz, "The Thermal Influence on the Daily Pressure Wave," *Bulletin of the American Meteorological Society*, vol. 36, No. 7, Sept. 1955, pp. 311–317.
9. W. J. Humphreys, *Physics of the Air*, (3d ed.), McGraw-Hill Book Co., Inc., New York, 1940, 661 pp.
10. G. R. Jenkins, "Diurnal Variation of the Meteorological Elements," *Handbook of Meteorology*, (F. A. Berry et al., eds.), McGraw-Hill Book Co., Inc., New York, 1945, pp. 746–753.
11. New York University, *Atmospheric Oscillations*, (Prog. Rep. 122–09, Contract AF19 (122)-49), New York, 1951.
12. J. Spar, "Thermal Influence in the Diurnal Pressure Wave," *Bulletin of the American Meteorological Society*, vol. 33, No. 8, Oct. 1952, pp. 339–343.
13. J. Spar, "Characteristics of the Semi-Diurnal Pressure Wave in the United States," *Bulletin of the American Meteorological Society*, vol. 33, No. 10, Dec. 1952, pp. 438–441.
14. U. S. Weather Bureau, "Ten-Year Normals of Pressure Tendencies and Hourly Station Pressures for the United States," Weather Bureau *Technical Paper* No. 1, 1943.
15. U. S. Weather Bureau, "Normal 3-Hourly Pressure Changes for the United States at the Intermediate Synoptic Hours," Weather Bureau *Technical Paper*, No. 1, Supplement, 1945.
16. M. V. Wilkes, *Oscillations of the Earth's Atmosphere*, Cambridge University Press, Cambridge 1949, 74 pp.

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